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# ENGLISH TRANSLATION OF INTERNATIONAL APPLICATION AS ORIGINALLY FILED

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DESCRIPTION

# PIEZOELECTRIC ELECTROACOUSTIC TRANSDUCER

## Technical Field

The present invention relates to a piezoelectric electroacoustic transducer, such as a piezoelectric sounder, a piezoelectric receiver, or a piezoelectric speaker.

## Background Art

Conventionally, as a piezoelectric sounder for generating warning sound or operating sound or a piezoelectric receiver, a piezoelectric electroacoustic transducer is widely used for electronics, home electric appliances, and a mobile phone. The above-mentioned piezoelectric electroacoustic transducer uses a quadrilateral piezoelectric diaphragm, thereby improving the production efficiency and the efficiency of acoustic transducer and reducing the size.

Patent Document 1 proposes a piezoelectric electroacoustic transducer, in which a quadrilateral piezoelectric diaphragm is accommodated in a case, the outer circumference of the piezoelectric diaphragm is supported by a supporting portion disposed on the inner circumference of the case, and an elastic sealant, e.g., silicone rubber, seals the space between the outer circumference of the piezoelectric diaphragm and the inner circumference of the case. In this case, conductive adhesives connect lead electrodes of the piezoelectric diaphragm and terminals fixed to the case so as to input an electrical signal to the piezoelectric diaphragm.

Patent Document 1: Japanese Unexamined Patent Application Publication No. 2003-9286

Generally, the conductive adhesive contains thermoset, as a basic member, and further contains a filler. Therefore, the conductive adhesive has a high Young's modulus after hardening and easily

restricts the diaphragm. Further, the hardening contraction stress of the conductive adhesive easily generates the distortion of the diaphragm. Recently, the diaphragm used for the piezoelectric electroacoustic transducer is excessively thin and small, and has the thickness of several tens to several hundreds μm. Therefore, the conductive adhesive even with an excessively small coat seriously influences on the vibrating property of diaphragm.

Conventionally, in order to suppress the force of constraint to the piezoelectric diaphragm due to the conductive adhesive, an elastic adhesive, e.g., urethane resin, is applied between the piezoelectric diaphragm and the terminal disposed on the case, and the conductive adhesive is applied on the elastic adhesive. In this case, the conductive adhesive is applied near each of the two corners on the diagonal lines of the four corners on the piezoelectric diaphragm. Since an elastic adhesive is applied under the conductive adhesive, the hardening contraction stress of the conductive adhesive is released, thereby preventing the generation of distortion of the diaphragm.

However, when the conductive adhesives are coated near two corners on the diagonal lines of the piezoelectric diaphragm as mentioned above, the force of constraint of diaphragm is large and the node of vibrations is close to the inside. Therefore, the wavelength of vibration is short and the resonant frequency is high in many cases.

Further, in accordance with the change in temperature under the using environment, the Young's modulus of the elastic adhesive or the conductive adhesive changes and therefore the force of constraint change. As a consequence, there is a problem of large change in resonant frequency of the diaphragm due to the change in temperature.

## Disclosure of Invention

### Problems to be Solved by the Invention

Then, it is an object of the present invention to provide a piezoelectric electroacoustic transducer, in which the coating positions of a conductive adhesives are devised, thus, the node of vibrations shifts to the outside, the resonant frequency of a diaphragm is lowered, and the change in the resonant frequency of the diaphragm as a result of temperature changes is small.

Means for Solving the Problems

In order to accomplish the object, according to the invention of Claim 1, there is provided a piezoelectric electroacoustic transducer comprising: a quadrilateral piezoelectric diaphragm that is bent for vibration in the thickness direction by applying an alternating signal to lead electrodes; a casing comprising a supporting portion disposed on an inner circumference of the casing, the supporting portion supports the outer circumference of the piezoelectric diaphragm; first and second terminals that are fixed to the casing so that inner connecting portions are exposed on the inner circumference of the casing; and conductive adhesives that are applied and are hardened between the lead electrodes of the piezoelectric diaphragm and the inner connecting portions of the first and second terminals, thereby the conductive adhesives electrically connect the lead electrodes to the inner connecting portions of the first and second terminals, wherein one of the conductive adhesives is applied and is hardened between the inner connecting portion of the first terminal and one of the lead electrodes near one corner of the piezoelectric diaphragm, and the other conductive adhesive is applied and is hardened between the inner connecting portion of the second terminal and the other lead electrode near another corner adjacent to the one corner.

Conventionally, the conductive adhesives are coated near the two corners at the diagonal positions of the diaphragm, the vibrations are obtained to approximately vibrate the diaphragm supported at both ends thereof.

On the other hand, according to the present invention, the conductive adhesives are coated near the corners along one side of the diaphragm and then the vibrations are obtained to vibrate the diaphragm supported at one end thereof, thereby more freely displacing the diaphragm. Thus, the node of vibrations shifts to the outside, the wavelength of vibrations is lengthened, and the resonant frequency is lowered. Further, when the environment of the using temperature changes, the change in the resonant frequency is suppressed because of the small change in force of constraint of the diaphragm due to the change in Young's modulus of the conductive adhesive.

According to Claim 2, the coating position of one conductive adhesive and that of another conductive adhesive may face each other, acrossing the piezoelectric diaphragm. Alternatively, according to Claim 3, the coating position of the one conductive adhesive and that of the other conductive adhesive may be on one side of the piezoelectric diaphragm and near the corners at both ends of the one side.

In every case, the operation and advantages according to Claim 1 are obtained.

When the two terminals are disposed on the two positions of the casing facing each other acrossing the casing, according to Claim 2, the coating positions of the conductive adhesives are determined at the two positions facing each other acrossing the piezoelectric diaphragm. This case is more preferable because the coating shape is simple and short, when the two terminals are disposed on the two positions of the casing facing each other acrossing the casing.

According to Claim 4, the piezoelectric diaphragm may be a unimorph diaphragm which is formed by adhering a quadrilateral piezoelectric member to a quadrilateral metallic plate. Alternatively, according to Claim 5, the piezoelectric diaphragm may be a bimorph diaphragm which is formed by laminating a plurality of piezoelectric

ceramics layers while sandwiching an inner electrode and providing principle-surface electrodes on principle surfaces of the front and back surfaces.

In the unimorph piezoelectric diaphragm, one lead electrode is an electrode disposed on the surface of the piezoelectric member and another lead electrode is the metallic plate.

Further, in the piezoelectric diaphragm with the laminated structure, one lead electrode is connected to the inner electrode and the other lead electrode is connected to the principle-surface electrodes.

According to Claim 6, preferably, an elastic adhesive may be coated between the piezoelectric diaphragm and the terminal and the conductive adhesive may be coated on the elastic adhesive.

An elastic sealant, e.g., silicone rubber seals the space between the outer circumference of the piezoelectric diaphragm and the inner circumference of the casing. Before the sealing operation, the piezoelectric diaphragm needs to be temporarily jointed to the casing. The temporarily-jointing operation is performed with the elastic adhesive, thereby keeping the positional precision between the piezoelectric diaphragm and the casing. Further, the conductive adhesive is constricted in the hardening and therefore the hardening contraction stress operates to the piezoelectric diaphragm, thereby changing the resonant frequency. However, since the elastic adhesive is coated under the conductive adhesive, the hardening contraction stress of the conductive adhesive is released by the elastic adhesive, thereby suppressing the influence to the stress to the piezoelectric diaphragm. The above-mentioned elastic member is, e.g., a urethane-series adhesive. Preferably, the Young's modulus after the hardening may be not more than $500\times10^6$ Pa.

Advantages

As will be obviously understood, according to the present

invention, the conductive adhesives are coated near the corners along one side of the diaphragm, thereby freely displacing other three sides of the diaphragm. Thus, the node of vibrations of the diaphragm shifts to the outside, the wavelength of vibrations is lengthened, and the resonant frequency is lowered. Further, with the change in environment of the using temperature, the change in the resonant frequency is suppressed because of the small change in force of constraint of the diaphragm due to the change in Young's modulus of the conductive adhesive.

## Brief Description of the Drawings

Fig. 1 is an exploded perspective view showing a piezoelectric electroacoustic transducer according to the first embodiment of the present invention;

Fig. 2 is a plan view showing a diaphragm which is held to a case (before coating an elastic sealant);

Fig. 3 is an enlarged cross-sectional view of a III-III line shown in Fig. 2;

Fig. 4 is an enlarged cross-sectional view of a IV-IV line shown in Fig. 2;

Fig. 5 is a plan view showing the case used for the piezoelectric electroacoustic transducer shown in Fig. 1;

Fig. 6 is a cross-sectional view of a VI-VI line shown in Fig. 5;

Fig. 7 is a cross-sectional view of a VII-VII line shown in Fig. 5;

Fig. 8 is an enlarged perspective view showing the corner on the left below of the case shown in Fig. 5;

Fig. 9 is a plan view and a contour plan showing the displacement of the diaphragm according to the first embodiment of the present invention;

Fig. 10 is a plan view and a contour plan showing the displacement

of the diaphragm according to a comparison with the first embodiment;

Fig. 11 is a comparing diagram showing the property of sound pressure between the present invention and the comparison;

Fig. 12 is a diagram showing the amount of change in frequency due to the change in temperature between the present invention and the comparison;

Fig. 13 is a plan view showing a piezoelectric electroacoustic transducer according to the second embodiment of the present invention;

Fig. 14 is a plan view showing a piezoelectric electroacoustic transducer according to the third embodiment of the present invention;

Fig. 15 is a perspective view showing a piezoelectric diaphragm used for the piezoelectric electroacoustic transducer shown in Fig. 14;

Fig. 16 is an analysis diagram showing the displacement of the diaphragm of the piezoelectric electroacoustic transducer shown in Fig. 14 using the finite element method;

Fig. 17 is a plan view according to a comparison with the third embodiment;

Fig. 18 is an analysis diagram showing the displacement of a diaphragm shown in Fig. 17 using the finite element method;

Fig. 19 is a perspective view showing a piezoelectric diaphragm according to the fourth embodiment of the present invention; and

Fig. 20 is a cross-sectional view of a XX-XX line shown in Fig. 19.

Best Mode for Carrying Out the Invention

Hereinbelow, a description is given of preferable embodiments of the present invention.

First embodiment

Figs. 1 to 8 show an example of a piezoelectric electroacoustic transducer, that is, a surface-mount electroacoustic transducer, such

as a sounder or ringer, suitable to the use with a single frequency, according to the present invention.

The electroacoustic transducer mainly includes a piezoelectric diaphragm 1, a case 10, and a cover 20.

Here, a casing includes the case 10 and the cover 20.

Referring to Fig. 2, the piezoelectric diaphragm 1 according to the first embodiment includes a square metallic plate 2 and a piezoelectric member 3 which is adhered at the position near one corner on the top surface of the metallic plate 2. The piezoelectric member 3 according to the first embodiment is rectangularly formed. However, the piezoelectric member 3 may be square. A piezoelectric member 3 is made of piezoelectric ceramics, e.g., PZT. Front and back surfaces of the piezoelectric member 3 entirely have electrodes 3a and 3b(electrode 3b on the back surface is not shown). An alternating signal is applied between the electrodes 3a and 3b on the front and back surfaces, thereby the piezoelectric member 3 expands and contracts in the plane direction. Preferably, the metallic plate 2 has good conductivity and also spring elasticity. For example, the metallic plate 2 may be made of phosphor bronze or 42Ni. Here, the metallic plate 2 is made of 42Ni with the coefficient of thermal expansion which is approximate to that of ceramic (e.g., PZT) having the dimensions in the vertical, horizontal, and thickness directions, i.e., 7.6 mm, 7.6 mm, and 0.03 mm. Further, the piezoelectric member 3 is made of a PZT plate having the dimensions in the vertical, horizontal, and thickness directions, i.e., 6.8 mm, 5.6 mm, and 0.04 mm.

The case 10 is square-box-shaped with a bottom wall 10a and four side walls 10b to 10e, and is made of a resin material, as shown in Figs. 5 to 8. Preferably, the resin material may be heat-resistant resin, e.g., LCP (liquid crystal polymer), SPS (syndiotactic polystyrene), PPS (polyphenylene sulfide), or epoxy. Among the four

side walls 10b to 10e, at the two places near the corners in the facing side-walls 10b and 10d, bifurcated inner connecting portions 11a and 12a of terminals 11 and 12 are exposed. The terminals 11 and 12 are inserted and molded in the case 10. Outer connecting portions 11b and 12b externally-exposed on the case 10 are bent to the bottom surface of the case 10 along the outer surfaces of the side walls 10b and 10d of the terminals 11 and 12 (refer to Fig. 7).

At four inner corners of the case 10, a supporting portion 10f for supporting the bottom surface of the corner of the diaphragm 1 is formed. The supporting portion 10f is formed lower than the exposed surfaces of the inner connecting portions 11a and 12a of the terminals 11 and 12 by one step. Therefore, when the diaphragm 1 is placed on the supporting portion 10f, the top surface of the diaphragm 1 has the same height of the top surface of the inner connecting portions 11a and 12a of the terminals 11 and 12, or the top surface of the diaphragm 1 has a height slightly lower than the top surface of the inner connecting portions 11a and 12a of the terminals 11 and 12.

Near the supporting portion 10f and on the inner circumference of the inner connecting portions 11a and 12a of the terminals 11 and 12, a urethane receiving step 10g is formed with the height lower than the supporting portion 10f with a predetermined space to the bottom surface of the diaphragm 1. The space between the top surface of the urethane receiving step 10g and the bottom surface of the diaphragm 1 (top surface of supporting portion 10f) is set with the dimension for preventing the flowage of an elastic adhesive 13 using the surface tension of the elastic adhesive 13, which will be described later.

Further, at the circumference of the bottom wall 10a of the case 10, a groove 10h for filling an elastic sealant 15, which will be described later, is disposed. In the groove 10h, a wall 10i for preventing the flow-out lower than the supporting portion 10f is disposed. The wall 10i for preventing the flowage regulates the

flowage of the elastic sealant 15 to the bottom wall 10a. The space between the top surface of the wall 10i and the bottom surface of the diaphragm 1 (top surface of the supporting portion 10f) is set with the dimension for preventing the flowage of the elastic sealant 15 using the surface tension thereof.

According to the first embodiment, the groove 10h is formed with low depth so that the bottom surface of the groove 10h is at the position higher than the top surface of the bottom wall 10a and the groove 10h is filled with a slightly small amount of the elastic sealant 15 to surround the periphery fast. The groove 10h and the wall 10i are disposed on the circumference of the bottom wall 10a excluding the urethane receiving step 10g. Or, the groove 10h and the wall 10i may be continuously disposed overall the bottom wall 10a, via the inner circumference of the urethane receiving step 10g.

Further, terminal portions (four corners) of the groove 10h which come into contact with the supporting portion 10f and the urethane receiving step 10g are widely formed, as compared with another portion. Therefore, the surplus adhesive 15 is absorbed by the wide portion, and the adhesive 15 prevents the flowage to the diaphragm 1.

At two portions of two adjacent corners near the center of the diaphragm 1 rather than the supporting portion 10f, receiving bases 10p for preventing the over-amplitude for preventing a predetermined amount of amplitudes of the diaphragm 1 are integrally projected from the bottom wall 10a of the case 10.

In the inner surfaces of the side walls 10b to 10e of the case 10, a taper-shaped projected portion 10j for guiding the four sides of the piezoelectric diaphragm 1 is disposed. The two projected portions 10j are individually disposed on the side walls 10b to 10e.

At the inner surfaces of the top edges of the side walls 10b to 10e of the case 10, caved portions 10k for regulating the rising of the elastic sealant 15 are formed.

Further, on the bottom wall 10a near the side wall 10e, a first sounder hole 101 is provided.

On the top surfaces of the corners of the side walls 10b to 10e in the case 10, L-shaped positioning projected portions 10m for holding and fitting the corners of the cover 20 are formed. On the inner surfaces of the projected portions 10m, taper surfaces 10n for guiding the cover 20 are formed.

Here, a description is given of an assembling method of the piezoelectric electroacoustic transducer with the above-mentioned structure.

First, the piezoelectric diaphragm 1 is accommodated in the case 10 so that the metallic plate 2 faces the bottom wall, the four corners of the piezoelectric diaphragm 1 are supported by the supporting portions 10f. In this case, the circumference of the diaphragm 1 is guided by the taper-shaped projected portions 10j disposed on the inner surfaces of the side walls 10b to 10e of the case 10. Therefore, the corners of the diaphragm 1 are precisely placed on the supporting portions 10f.

After accommodating the diaphragm 1 in the case 10, the elastic adhesive 13 is applied to two portions near the adjacent corners of the diaphragm 1, thereby temporarily fixing the diaphragm 1 (metallic plate 2) to the case 10. In particular, the metallic plate 2 is coated with the one elastic adhesive 13, as shown in Fig. 3. A conductive adhesive 14 coated on the elastic adhesive 13 prevents the contact state to the metallic plate 2. When the strength for temporary fixing of the diaphragm 1 is to be increased, the elastic adhesive 13 may coat the two remaining portions near the adjacent corners of the diaphragm 1. Here, the elastic adhesive 13 is linearly applied to the outer side surface of the diaphragm 1. However, the coating shape is not limited to this. As the elastic adhesive 13, preferably, an adhesive with Young's modulus of $500\times10^6$ Pa or less

after the hardening is used. According to the first embodiment, a urethane-series adhesive with Young's modulus of $3.7\times10^{6}$ Pa is used. After coating the elastic adhesive 13, the heating and hardening processing is performed.

Upon coating the elastic adhesive 13, the elastic adhesive 13 might flow and fall to the bottom wall 10a via the space between the piezoelectric diaphragm 1 and the terminal 11 or 12. However, as shown in Fig. 3, the urethane receiving step 10g is disposed on the down portion of the piezoelectric diaphragm 1 in an area coated with the elastic adhesive 13. The space between the urethane receiving step 10g and the piezoelectric diaphragm 1 is set to be narrow. Therefore, the flow of the elastic adhesive 13 is prevented by the surface tension of the elastic adhesive 13, thereby preventing the flowage to the bottom wall portion 10a. Further, since the space is fast filled, the surplus elastic adhesive 13 is formed with a projected portion between the piezoelectric diaphragm 1 and the terminal 11 or 12. The layer of the elastic adhesive 13 exists between the urethane receiving step 10g and the piezoelectric diaphragm 1. Thus, the piezoelectric diaphragm 1 is not restrained at the unnecessary level.

After hardening the elastic adhesive 13, the conductive adhesive 14 is applied to the up portion of the elastic adhesive 13. Various conductive adhesive may be used. According to the first embodiment, a urethane-series conductive paste is used with Young's modulus of $0.3\times10^{9}$ Pa after the hardening. After applying the conductive adhesive 14, the conductive adhesive 14 is heated and hardened, thereby electrically connecting the metallic plate 2 to the inner connecting portion 11a of the terminal 11 and further the surface electrode 3a of the piezoelectric member 3 to the inner connecting portion 12a of the terminal 12. In particular, the applying length of the conductive adhesive 14 conneting the electrode 3a of the piezoelectric member 3

to the inner connecting portion 12a of the terminal 12 is shortened because the piezoelectric member 3 is positioned near one corner of the metallic plate 2. Then, under the conductive adhesive 14, the elastic adhesive 13 exists and coats the metallic plate 2, thereby preventing the directly contact state of the conductive adhesive 14 with the metallic plate 2. The coating shape of the conductive adhesive 14 is not limited and may connect, via the top surface of the elastic adhesive 13, the metallic plate 2 or the surface electrode 3a of the piezoelectric member 3 to the inner connecting portion 11a of the terminal 11 or the inner connecting portion 12a of the terminal 12. The elastic adhesive 13 is projected and therefore the conductive adhesive 14 is applied like arch to the top surface of the elastic adhesive 13, that is, the applied conductive adhesive 14 is not the shortest route. Therefore, the hardening contraction stress of the conductive adhesive 14 is reduced by the elastic adhesive 13, thereby suppressing the influence on the diaphragm 1.

After applying and hardening the conductive adhesive 14, the elastic sealant 15 is applied to the space between the entire circumference of the diaphragm 1 and the inner circumference of the case 10, thereby preventing the air leakage between the front side and the back side of the diaphragm 1. After circularly applying the elastic sealant 15, the elastic sealant 15 is heated and hardened. As the elastic sealant 15, a thermal hardening adhesive may be used with Young's modulus of $30\times10^6$ Pa or less after the hardening and a low degree of viscosity before the hardening. Here, a silicone-series adhesive is used as the elastic sealant 15. At the inner circumference of the case 10 facing the circumference of the diaphragm 1, the groove 10h is disposed to fill the elastic sealant 15. In the groove 10h, the wall 10i for preventing the flowage is disposed. The elastic sealant 15 enters the groove 10h, and is circumferentially spread. Between the diaphragm 1 and the wall 10i for preventing the

flowage, the space for preventing the flowage of the elastic sealant 15 using the surface tension thereof is formed. The flowage of the elastic sealant 15 to the bottom wall 10a is prevented. Between the wall 10i and the piezoelectric diaphragm 1, the layer of the elastic sealant 15 exists. Therefore, the suppression of vibrations of the piezoelectric diaphragm 1 is prevented.

As mentioned above, after attaching the diaphragm 1 to the case 10, the cover 20 is adhered to the top surfaces of the side walls of the case 10 with an adhesive 21. The cover 20 is formed like a plane with the same material as that of the case 10. The circumference of the cover 20 is engaged with inner taper surfaces 10n of the positioning projected portions 10m projected to the top surfaces of the side walls of the case 10, thereby performing the precise positioning. The cover 20 is adhered to the case 10, thereby forming the acoustic space between the cover 20 and the diaphragm 1. The cover 20 has a second sounder hole 22.

As mentioned above, the surface-mount piezoelectric electroacoustic transducer is assembled.

According to the first embodiment, a predetermined alternating signal (AC signal or rectangular-wave signal) is applied between the terminals 11 and 12, thereby expanding and contracting the piezoelectric member 3 in the plane direction without expansion and contraction of the metallic plate 2. Therefore, as a whole, the diaphragm 1 is bent for vibration. The elastic sealant 15 seals the interval between the front side and the back side of the diaphragm 1. Therefore, predetermined sound waves are generated through the sounder hole 22.

Fig. 9 shows the coating position of the conductive adhesive and the displacement of the diaphragm in the piezoelectric electroacoustic transducer according to the present invention.

Fig. 10 shows the coating position of a conductive adhesive and

the displacement of a diaphragm in a piezoelectric electroacoustic transducer according to a comparison.

According to the present invention, the conductive adhesive 14 is applied near each of the two adjacent corners of the diaphragm 1. On the other hand, according to the comparison, the conductive adhesive 14 is applied near each of the two corners on the diagonal lines of the diaphragm 1, the elastic adhesive 13 is applied to the back side of the conductive adhesive 14, and the diaphragm 1 and the case 10 have the same shape.

As will be obviously understood with reference to Fig. 10, according to the comparison, the conductive adhesive 14 is applied near each of the two corners on the diagonal lines. Then, a node K of vibrations of the diaphragm 1 is near the inside, and the displacement of vibrations is elliptical. As a result, the resonant frequency of the diaphragm 1 is high.

On the contrary, according to the present invention, the conductive adhesive 14 is applied near each of the two adjacent corners of the diaphragm 1. Then, referring to Fig. 9, the node K of vibrations of the diaphragm 1 shifts to the outside and the displacement of vibrations is circular without distortion. Therefore, unlike the comparison, the resonant frequency of the diaphragm 1 is lowered.

Fig. 11 shows the properties of sound pressure according to the present invention and the comparison.

According to the present invention, the peak of level of the sound pressure shifts to the lower-frequency side, as compared with that according to the comparison.

Fig. 12 shows the amount of change in frequency due to the temperature change according to the present invention and the comparison.

According to the comparison, with the change in temperatures

ranging 25 °C to -40 °C, the amount of change in frequency is approximately 0.18 kHz. On the contrary, according to the present invention, the amount of change in frequency is approximately 0.07 kHz. The change in frequency due to the temperature change according to the present invention is lower than the half of the comparison.

Second embodiment

According to the first embodiment, the conductive adhesive 14 is applied to the facing positions near the two adjacent corners of the diaphragm 1. However, referring to Fig. 13, the conductive adhesive may be applied to the positions near the two corners on one side of the diaphragm 1.

The above-mentioned structure can be applied to the case, in which the inner connecting portions 11a and 12a of the terminals 11 and 12 are exposed along one side of the case 10.

Third embodiment

Figs. 14 shows an example of a piezoelectric electroacoustic transducer using the unimorph diaphragm 20 with the shape different from that according to the first embodiment. Fig. 15 shows the unimorph diaphragm 20. The same portions as those according to the first embodiment are designated by the same reference numerals, and a description thereof is omitted here.

Referring to Fig. 15, the diaphragm 20 has a piezoelectric member 22 which is adhered to the position near one side of the metallic plate 21. Materials of the metallic plate 21 and the piezoelectric member 22 are the same as those according to the first embodiment. However, the metallic plate 21 has the dimensions in the vertical, horizontal, and thickness directions, i.e., 7.6 mm, 7.6 mm, and 0.03 mm, and the piezoelectric member 22 has the dimensions in the vertical, horizontal, and thickness directions, i.e., 5.3 mm, 7.6 mm, and 0.04 mm.

According to the third embodiment, the conductive adhesive 14 is

applied to the facing positions near the two adjacent corners of the diaphragm 20.

Fig. 16 shows the displacement of the diaphragm 20 when the conductive adhesive 14 is applied to the positions near the two adjacent corners of the diaphragm 20 as shown in Fig. 14.

As will be clearly understood with reference to Fig. 16, the conductive adhesive 14 is applied to the positions near the two adjacent corners of the diaphragm 20. Therefore, the node K of the vibrations shifts to the outside and the displacement of vibrations is circular without low distortion. Thus, the resonant frequency of the diaphragm 20 is lowered.

Fig. 17 shows the example in which the conductive adhesive 14 is applied to the positions near the two corners on the diagonal lines with the diaphragm 20 according to the third embodiment. Fig. 18 shows the displacement of the diaphragm 20.

Referring to Fig. 18, the node K of the vibrations of diaphragm 20 is near the inside at the two corners on the diagonal lines on which the conductive adhesive 14 is disposed, and the displacement of vibrations is elliptically distorted. As a result, the resonant frequency of the diaphragm 20 is high.

As will be obviously understood according to the first and third embodiments, the conductive adhesive is applied to the positions near the two adjacent corners of the diaphragm, independently of the shapes of the diaphragms 1 and 20. The node K of the vibrations shifts to the outside and the resonant frequency is lowered.

Fourth embodiment

The piezoelectric diaphragm is not limited to the unimorph diaphragm which is formed by adhering the piezoelectric member to the metallic plate and may be a piezoelectric diaphragm with the bimorph structure comprising laminated layers of piezoelectric ceramic, as shown in Figs. 19 and 20.

A diaphragm 30 is disclosed in, e.g., Japanese Unexamined Patent Application Publication No. 2001-95094. The diaphragm 30 is formed by laminating two piezoelectric ceramics layers 31 and 32, the principal surfaces on the front and back sides of the diaphragm 30 have principle-surface electrodes 33 and 34, and an inner electrode 35 is formed between the ceramics layers 31 and 32. The two ceramics layers 31 and 32 are polarized in the same direction of the thickness. The principle-surface electrode 33 on the front side and the principle-surface electrode 34 on the back side are formed with the lengths shorter than that of the side of the diaphragm 30, and first ends of the principle-surface electrode 33 on the front side and the principle-surface electrode 34 on the back side are connected to an end electrode 36 formed to one end-surface of the diaphragm 30. Therefore, the principle-surface electrode 33 on the front side and the principle-surface electrode 34 on the back side are connected to each other. The inner electrode 35 is symmetrically formed to the principle-surface electrodes 33 and 34, one end of the inner electrode 35 is separated from the end electrode 36, and the other end of the inner electrode 35 is connected to an end electrode 37 formed to another end surface of the diaphragm 30. An auxiliary electrode 38 which is conductive to the end electrode 37 is formed on the front and back sides of the other end of the diaphragm 30.

On the front and back surfaces of the diaphragm 30, a resin layer 39 for coating the principle-surface electrodes 33 and 34 is formed. The resin layer 39 is disposed so as to improve the strength against the falling because the diaphragm 30 is made of ceramic material. Then, the resin layer 39 on the front and back sides comprises, a notch 39a, in which the principle-surface electrodes 33 and 34 are exposed, and a notch 39b in which the auxiliary electrode 38 is exposed, near two adjacent corners of the diaphragm 30.

The notches 39a and 39b may be disposed only on one of the front

and back sides. in the embodiment, to obtain the non-directivity of the front and back sides, the notches 39a and 39b are disposed on both the front and back sides.

Further, the auxiliary electrode 38 does not need to have a band electrode with a constant width. The auxiliary electrode may be disposed only at the position corresponding to the notch 39b.

The diaphragm 30 is accommodated in the case 10 similarly to that shown in Figs. 5 to 8, the elastic adhesive 13 is applied between the principle-surface electrode 33 exposed in the notch 39a at the facing position and the inner connecting portion 11a of the terminal 11, and between the auxiliary electrode 38 exposed in the notch 39b and the inner connecting portion 12a of the terminal 12, and the diaphragm 30 is temporarily fixed to the case 10.

After that, similarly to according to the first embodiment, the conductive adhesive 14 is applied on the elastic adhesive 13 and is hardened. Further, the elastic sealant 15 is applied to seal the space between the outer circumference of the diaphragm 30 and the inner circumference of the case 10.

According to the fourth embodiment, the conductive adhesive 14 is applied to the positions near the adjacent corners of the diaphragm 30. Therefore, the force of constraint of the diaphragm 30 is lower, as compared with the case of applying the conductive adhesive to the positions near the two corners on the diagonal line. Accordingly, the node of vibrations shifts to the outside and the resonant frequency is lowered.

The present invention is not limited to the above-mentioned embodiments and can be modified without departing the essentials of the present invention.

According to the embodiments, the piezoelectric member 3 is a single plate. In place of the single piezoelectric-member 3, the present invention may apply a diaphragm which is formed by adhering,

to a metallic plate, a member excluding the resin layer 39 from the piezoelectric diaphragm 30 according to the third embodiment.

According to the embodiments, the diaphragm is approximately square, however the diaphragm may be rectangular. In this case, preferably, the conductive adhesive may be applied to the positions near the corners on both ends of one short side.

With the diaphragm of the unimorph structure, as shown in Fig. 1, the piezoelectric member is adhered near one corner of the metallic plate. In addition, the diaphragm may be formed by adhering the piezoelectric member at the center of the metallic plate, or, may be formed by adhering the piezoelectric member at one side of the metallic plate.

As mentioned above, the piezoelectric diaphragm according to the present invention may have any shape and structure in so far as the piezoelectric diaphragm is quadrilateral.